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# IRON TOXICITY IN TRITICUM AESTIVUM L. SEEDLINGS: A CONCENTRATION- AND TIME-DEPENDENT ANALYSIS OF MORPHOPHYSIOLOGICAL, OXIDATIVE, AND ANTIOXIDANT RESPONSES

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*Abstract*
*Iron (Fe) is an inevitable micronutrient essential for all living organisms; however, its excess can disrupt cellular metabolism and induce oxidative stress. This study investigated the concentration- and time-dependent effects of Fe toxicity on growth, oxidative damage, and antioxidant responses in Triticum aestivum L. (wheat) seedlings exposed to 0, 100, 200, and 500 µM Fe-EDTA for up to 14 days. Moderate Fe exposure (100 µM) promoted seedling growth, resulting in an 11.3% increase in shoot length and 18.4% increase in fresh biomass on the $12^{th}$ day compared with the control. In contrast, 500 µM Fe significantly inhibited growth, causing a 23.6% reduction in root length by the $14^{th}$ day. Excess Fe enhanced oxidative stress, as reflected by increased MDA (malondialdehyde) and $H_2O_2$ (hydrogen peroxide) accumulation. The highest MDA was recorded under 500 µM Fe, showing increases of 35.2% and 39.4% in shoot and root tissues, respectively, on the $14^{th}$ day. Increased oxidative stress was accompanied by activation of antioxidant defenses, with catalase (CAT) activity increasing up to 3.67-fold and ascorbate peroxidase (APX) activity increasing by 61.5% under Fe stress. Overall, prolonged exposure to elevated Fe concentrations induced oxidative damage and growth inhibition in wheat seedlings, while enhanced antioxidant enzyme activities contributed to mitigating Fe-induced cellular injury. These findings improve our understanding of the temporal responses of wheat seedlings to excess Fe and the participation of antioxidant systems in mitigating stress-induced damage.*

*Keywords: Antioxidant enzyme, Defense mechanism, Iron, Tolerance, Toxicity, Triticum aestivum,*

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## 1. Introduction

Iron (Fe) is an indispensable micronutrient required for several processes in plants, such as metabolic and physiological. Fe is the crucial component in the electron transport system of photosynthesis, respiration, nitrogen assimilation as well as involve in chlorophyll biosynthesis. However, the presence of Fe in soil at a toxic level led to a negative impact on the agricultural productivity of various crops (Finatto et al., 2015). Accumulation of excess iron mainly depends on many factors such as soil acidity, high active iron, waterlogged conditions, and reduced oxides (Connolly and Guerinot, 2002). Furthermore, soil aluminium (Al) availability remains linked to soil conditions irrespective of organic matter content and textural characteristics (Garrity et al., 1986). Accumulation of $H_2S$, and growth factor may also produce Fe-toxicity. Flooded soil as well as low pH conditions promote reduction of ferric form of iron to ferrous form, which also causes Fe stress (Fageria et al., 2011). Emphatically, Fe toxicity is a major agricultural constraint, especially in crops cultivated under acidic soil conditions.

Excessive Fe can disrupt metabolic processes and induce oxidative injury in plant tissues. Symptoms associated with Fe toxicity include reduction in root growth, leaf bronzing, and decreased concentrations of essential cations (Çelık et al., 2010). In addition, Fe excess has been associated with reduced mineral nutrient uptake, protein degradation, impairment of enzymatic functions, and increased generation of reactive oxygen species, resulting in cellular oxidative stress (Sandalio et al., 2001). To cope with excess Fe, plants have developed multiple protective mechanisms that reduce the buildup of free iron in cells. These include limiting Fe entry through the roots, immobilizing Fe in the rhizosphere, compartmentalizing it within vacuoles, storing it in ferritin complexes, and strengthening antioxidant defence pathways (Wu et al., 2014).

Plants possess an efficient antioxidant defense network that includes both enzymatic and non-enzymatic components, enabling them to counteract the harmful effects of reactive oxygen species (ROS) generated during abiotic stress conditions (Sharma et al., 2024; 2025). Under metal-induced stress, the production of ROS generally increases, triggering the activation of several antioxidant enzymes. Among these, APX (ascorbate peroxidase), SOD (superoxide dismutase), POD (peroxidase), CAT (catalase), and GR (glutathione reductase) play crucial roles in detoxifying reactive oxygen species and maintaining cellular redox balance. (Sharma et al., 2024; 2025). Besides enzymatic antioxidants, several endogenous metabolites such as cycteine, glycine, and alanine contribute to stress tolerance by mitigating metal-induced cellular injury (Kumar et al., 2016). Among these metabolites, glutathione (GSH) plays a particularly important role in maintaining cellular redox balance and detoxifying excess metals, thereby enhancing plant tolerance to metal stress (Sharma et al., 2024; 2025).

Iron toxicity is a major constraint affecting wheat growth and productivity, particularly under conditions of excessive Fe availability. Despite its essential role in plant metabolism, elevated Fe levels can disrupt cellular homeostasis and induce oxidative damage. Therefore, the present study was undertaken to examine the concentration and time-dependent effects of Fe stress on the growth and physiological performance of *T. aestivum* seedlings. Morphological characteristics were monitored at regular intervals to evaluate the progression of Fe-induced toxicity. In addition, oxidative stress indicators, including hydrogen peroxide and malondialdehyde (MDA), were analyzed to assess cellular damage. The activities of key antioxidant enzymes, namely catalase (CAT) and ascorbate peroxidase (APX) were also investigated to understand the adaptive responses of wheat seedlings against Fe-induced oxidative stress. This study provides insights into the temporal relationship between Fe exposure, oxidative injury, and antioxidant defence mechanisms in wheat.

## 2. Material And Methodology

### 2.1 Plant Cultivation

Seeds of *Triticum aestivum* variety Raj 3765 were procured from the NBPGR. Prior to germination, seeds were sterilized with mercuric chloride (0.1% w/v) for one two min, followed by repeated washing with double distilled water to eliminate traces of the sterilizing residues. The sterilized seeds were then placed in glass petri dishes lined with whatman filter paper, moistened with autoclaved distilled water and incubated under dark conditions for germination. After germination, uniform and healthy seedlings were selected and transferred to Hoagland nutrient solution adjusted to pH 5.8. One week old seedlings were exposed to different concentrations of Fe supplied as Fe-EDTA (0 µM control, 100 µM, 200 µM, and 500 µM). Throughout the experimental period, seedlings were grown under controlled environmental conditions at 25 ℃ with 50% relative humidity. The nutrient medium was replaced every three days to ensure a continuous supply of nutrients, while regular aeration was provided twice daily to maintain adequate oxygen levels. Plant tissues were harvested at specific time points to evaluate the morphological and biochemical changes induced by Fe treatment.

### 2.2 Measurement of Growth Parameters

Seedlings were harvested and gently rinsed with distilled water before recording growth attributes. Root and shoot length were measured in centimetres, while fresh and dry biomass were determined in grams.

### 2.3 Assessment of Oxidative Stress Markers (MDA and $H_2O_2$)

The extent of lipid peroxidation was estimated by measuring MDA (malondialdehyde) content following De Vos et al. (1989). Fresh root and shoot tissues were homogenized in 10% TCA containing 0.25% TBA, incubated for thirty min at 95 ℃, rapidly cooled on ice, and centrifuged at 10,000×g for 15 min. The absorbance of the resulting supernatant was recorded at 532 and 600 nm. MDA levels were then calculated using an extinction coefficient of 155 $mM^{-1} cm^{-1}$.

The level of hydrogen peroxide ($H_2O_2$) was estimated following the protocol described by Alexieva et al. (2001). Fresh tissues were homogenized in chilled TCA (0.1%) and subsequently centrifuged at 10,000×g for 15 min. The resulting supernatant was added with potassium iodide and phosphate buffer (pH 7.0), incubated in the dark for 1 h, and the

absorbance was recorded at 390 nm. $H_2O_2$ concentration was quantified using an extinction coefficient of 0.28 μmol$^{-1}$ cm$^{-1}$.

**2.4 Extraction and Assay of Antioxidant Enzymes**

Fresh plant tissues were homogenized in chilled 50 mM sodium phosphate buffer (pH 7.0) and centrifuged at 10,000×g for 20 min at 4 °C. The obtained supernatant served as the crude enzyme extract for antioxidant assays. Catalase (CAT) activity was estimated following Aebi (1974) by monitoring the decomposition of $H_2O_2$ at 240 nm. The reaction mixture had enzyme extract, phosphate buffer (50 mM, pH 7.0), and 9 mM $H_2O_2$, and enzyme activity was calculated using an extinction coefficient of 0.039 mM$^{-1}$ cm$^{-1}$. Ascorbate peroxidase (APX) activity was measured according to Chen and Asada (1989) by recording the decline in absorbance at 290 nm due to ascorbate oxidation. The assay mixture consisted of enzyme extract, phosphate buffer (pH 7.0), and $H_2O_2$, and APX activity was estimated using an extinction coefficient of 2.8 mM$^{-1}$ cm$^{-1}$.

**2.5 Statistical Analysis**

All experiments were conducted with three independent biological replicates for both control and treated groups. Data are presented as mean standard error (SE). Graphs were generated using SigmaPlot version 14.0.

**3 Results**

**3.1 Effect of Fe Stress on Root and Shoot Length**

Shoot growth showed variable responses depending on Fe concentration and duration of exposure (Table 1). Compared with the control, seedlings treated with 100 µM Fe exhibited a stimulatory effect on shoot elongation, with shoot length increasing by 6.9%, 9.2%, 13.3% and 11.3% on the 2$^{nd}$, 4$^{th}$, 10$^{th}$, and 12$^{th}$ days, respectively. The maximum increase was recorded on the 12$^{th}$ day, representing an 11.3% enhancement over the control. Similarly, 200 µM Fe caused a modest increase in shoot length on the 2$^{nd}$ day (2.2%) and 10$^{th}$ day (8.7%), although values remained close to those of the control at later stages. In contrast, 500 µM Fe adversely affected shoot development, causing reductions of 21.3%, 15.0%, and 11.4% on the 6$^{th}$, 12$^{th}$, and 14$^{th}$ days, respectively, relative to the control.

Root growth was more susceptible to elevated Fe levels than shoot growth. Exposure to 100 µM Fe resulted in a 13.3% increase in root length on the 2$^{nd}$ day and an 18.0% increase on the 12$^{th}$ day compared with the corresponding control values, while only minor differences were observed during the remaining sampling periods. Seedlings treated with 200 µM Fe displayed marked reductions in root elongation, particularly on the 4$^{th}$ and 8$^{th}$ days, where root length declined by 16.6% and 24.2%, respectively. The strongest inhibitory effect was observed under 500 µM Fe. Root length decreased by 23.3%, 16%, and 23.6% on the 8$^{th}$, 12$^{th}$, and 14$^{th}$ days, respectively, compared with the control. On the 14$^{th}$ day, seedlings exposed to 500 µM Fe exhibited a root length 23.6% lower than that of the control (Table 1).

**3.2 Effect of Fe Stress on Seedling Biomass**

Fresh and dry biomass of wheat seedlings exhibited concentration and duration dependent variations under Fe treatment (Table 2). During the initial stages of exposure, only minor changes in fresh weight were observed among the treatments. Seedlings exposed to 100 µM Fe showed a stimulatory response, with fresh biomass increasing by 13.1% and 18.4% over the control on the 10$^{th}$ and 12$^{th}$ days, respectively. The highest fresh was recorded in the 100 µM treatment on 12$^{th}$ day with 18.4% increment.

In contrast, prolonged exposure to elevated Fe concentrations adversely affected biomass accumulation. Seedlings treated with 200 µM Fe exhibited a gradual decline in fresh weight, particularly on the 8$^{th}$ and 12$^{th}$ days, showing reductions of 14.7% and 9.4%, respectively, compared with the control (Table 2). The inhibitory effect was more pronounced at 500 µM Fe, where fresh biomass decreased by 12.4%, 10.8%, 19.7%, and 20% on the 6$^{th}$, 8$^{th}$, 12$^{th}$, and 14$^{th}$ days, respectively. The maximum reduction in fresh weight was observed on the 14$^{th}$ day, where seedlings exposed to 500 µM Fe exhibited a 20% decline compared with the control (Table2).

A similar trend was evident for dry biomass. Seedlings treated with 100 µM Fe showed enhanced dry matter accumulation at later stages of growth, with increases of 8.8%, 10.2% and 26.1% on the 6$^{th}$, 10$^{th}$, and 12$^{th}$ days, respectively, relative to the control. Conversely, 500 µM Fe markedly restricted dry biomass production, causing reductions of 18.5%, 3.8%, and 7.5% on the 2$^{nd}$, 6$^{th}$, and 14$^{th}$ days, respectively (Table 2). Dry weight under 200 µM Fe remained largely comparable to the control throughout the experiment, with only slight fluctuations. Overall, these findings suggest that moderate Fe exposure (100 µM) promoted biomass, whereas prolonged exposure to higher Fe concentrations, particularly 500 µM, impaired seedling growth and reduced biomass production.

**3.3 Effect of Fe Stress on MDA Accumulation in Shoot and Root Tissue**

Malondialdehyde (MDA) content in both shoot and root tissues varied with Fe concentration and duration of exposure, indicating differential oxidative responses under Fe stress, as shown in Figure 1. In shoots, MDA levels were low in seedlings of the control and other Fe treatments on initial days. While from the 6$^{th}$ day onwards, MDA accumulation displayed a distinct concentration-dependent pattern. Although MDA levels under 100 and 200 µM Fe were lower than those of the control on the 6$^{th}$ day, exposure to 500 µM Fe continued to maintain elevated oxidative damage. A marked increase in lipid peroxidation was observed on the 8$^{th}$ day, when MDA content increased by 105.0%, 78.6%, and 107.5% under 100, 200, and 500 µM Fe treatments, respectively, relative to the control (Fig. 1a). At later stages of exposure, seedlings subjected to 500 µM Fe consistently exhibited the highest MDA accumulation. Compared with the control, MDA content increased by 7.1%, 16.3%, and 35.2% on the 10$^{th}$, 12$^{th}$, and 14$^{th}$ days, respectively, with the greatest elevation recorded on the 14$^{th}$ day. In contrast, moderate Fe treatments (100 and 200 µM) induced comparatively smaller fluctuations in MDA levels throughout the experimental period (fig. 1a).

Similarly, root tissues exhibited enhanced lipid peroxidation with increasing Fe concentration and treatment duration. During the initial stages, only slight changes were observed; however, from the 6$^{th}$ day onwards, MDA accumulation increased substantially. On the 8$^{th}$ day, root MDA content increased by 24.1%, 44.5%, and 69.7% under 100, 200, and 500 µM Fe, respectively (Fig. 1b). The highest MDA accumulation was recorded on the 14$^{th}$ day, with increases of 28.1%, 26.9%, and 39.4% under 100, 200, and 500 µM Fe, respectively, relative to the control. A 3.16-fold increase in root MDA content was observed under 500 µM Fe on the 14$^{th}$ day compared with the 2nd day of exposure (Fig. 1b).

**3.4 Effect of Fe Stress on $H_2O_2$ Content in Shoot and Root Tissue**

Levels of Hydrogen peroxide ($H_2O_2$) in both shoot and root tissues were markedly influenced by Fe concentration and duration of exposure (Fig. 1). In shoots, $H_2O_2$ accumulation remained comparable to the control during the early stages of treatment but increased progressively under elevated Fe concentrations. The most pronounced effect was observed at 500 µM Fe, where $H_2O_2$ content increased by 33.8%, 47%, and 24.3% on the 10$^{th}$, 12$^{th}$, and 14$^{th}$ days, respectively, compared with the corresponding controls. Seedlings exposed to 200 µM Fe also exhibited enhanced $H_2O_2$ accumulation, particularly on the 12$^{th}$ day, showing a 50.1% increase over the control (Fig. 1c).

Root tissues displayed a similar trend, although the magnitude of change was more evident during prolonged exposure. $H_2O_2$ levels under 500 µM Fe increased by 40.6%, 56.7%, and 48.3% on the 10$^{th}$, 12$^{th}$, and 14$^{th}$ days, respectively, relative to the control. Likewise, 200 µM Fe resulted in increases of 26.8%, 28.8%, and 27.0% at the corresponding sampling periods. In contrast, seedlings treated with 100 µM Fe showed only minor fluctuations during the initial stages and exhibited comparatively lower $H_2O_2$ accumulation than the higher Fe treatments (Fig. 1d).

**3.5 Effect of Fe Stress on Catalase Activity**

Catalase (CAT) activity in both shoot and root tissues was significantly influenced by Fe concentration and exposure duration (Fig. 2). In shoots, CAT activity exhibited a pronounced increase under Fe stress, particularly at higher concentrations. The strongest induction was observed under 500 µM Fe on the 6$^{th}$ day, where CAT activity increased approximately 3.7-fold compared with the control. Thereafter, CAT activity remained elevated and reached its highest value under 100 µM Fe on the 14$^{th}$ day, showing a 50.0% increase over the corresponding control (Fig. 2a). Moderate Fe treatments (100 and 200 µM) generally stimulated CAT activity during prolonged exposure, indicating enhanced antioxidant defense against Fe-induced oxidative stress.

Root CAT activity showed a comparatively moderate response during the initial stages of treatment but increased with prolonged exposure. The highest CAT activity was recorded under 200 µM Fe on the 14$^{th}$ day, representing a 57.2% increase over the control (Fig. 2b). Similarly, CAT activity under 500 µM Fe remained consistently higher than the control throughout the experiment, with the greatest increase (40.0%) observed on the 8$^{th}$ day (Fig. 2b).

**3.6 Effect of Fe Stress on Ascorbate Peroxidase Activity**

APX activity increased in both shoot and root tissues in response to Fe treatment, particularly during the later stages of exposure (Figure 2). In shoots, APX activity was enhanced under all Fe concentrations, with the most pronounced increase observed under 500 µM Fe on the 10$^{th}$ day, where activity was 61.5% higher than the control (Fig. 2c). Elevated APX activity was maintained until the 14$^{th}$ day, showing increases of 12.6%, 29.2%, and 46.6% under 100, 200, and 500 µM Fe, respectively, compared with the corresponding control (Fig. 2c).

Root APX activity also exhibited a gradual rise with increasing exposure duration as shown in Figure 2d. The highest stimulation was recorded under 200 µM Fe on the 14$^{th}$ day, where APX activity increased by 33.5% relative to the control. At the same time point, APX activity under 100 and 500 µM Fe was elevated by 15.3% compared with the control (Fig. 2d). These results indicate that APX-mediated detoxification of $H_2O_2$ was enhanced under Fe stress, particularly during prolonged exposure.

**4 Discussion**

Iron plays a central role in metabolism as a cofactor for numerous enzymes involved in photosynthesis, respiration and redox reactions. However, excess Fe can become detrimental because it promotes the formation of ROS through Fenton and Haber-Weiss reactions, leading to oxidative damage (Becana et al., 1998, Li et al., 2019). The present study demonstrated that the response of wheat seedlings to Fe exposure was both concentration and time dependent, with moderate Fe levels showing beneficial effects on growth, whereas prolonged exposure to elevated Fe concentrations induced oxidative stress and growth inhibition. Growth parameters revealed that 100 µM Fe promoted shoot elongation and biomass accumulation during the later stages of growth, indicating that moderate Fe availability supported normal metabolic activities. In contrast, prolonged exposure to 500 µM Fe resulted in a marked reduction in shoot and root growth. Likewise, growth reduction has been observed in *Oryza sativa* (Pinto et al., 2016) and *Solanum lycopersicum* (Das et al., 2020). Moreover, Kabir et al. (2016) observed reduced growth in BR 26 wheat variety at higher Fe concentration. Overall, these findings indicate that moderate Fe exposure (100 µM) slightly promoted seedling growth, whereas prolonged exposure to higher Fe concentrations, particularly 500 µM, substantially restricted growth, with roots being more sensitive than shoots to Fe-induced toxicity.

Oxidative stress due to high Fe concentration is reflected by the elevated ROS and MDA in wheat seedlings, which was brief in Figure 1. The rise in $H_2O_2$ and MDA levels observed in both shoot and root tissues clearly indicates the development of oxidative stress under excess Fe. MDA is a well-recognised indicator of membrane lipid peroxidation, while $H_2O_2$ serves both as a ROS and signalling molecule during stress responses (Gill and Tuteja, 2010). The progressive accumulation of these markers with increasing Fe concentration and exposure duration suggests enhanced ROS production and disruption of cellular redox homeostasis. Similar increases in MDA and $H_2O_2$ under Fe toxicity have been reported in wheat, rice, and other crop species (Fang et al., 2001; Stein et al., 2009). The highest MDA

accumulation observed under 500 µM Fe on the 14th day further indicates severe membrane deterioration from prolonged oxidative stress.
To counteract ROS toxicity, plants activate enzymatic antioxidant systems. In the present study, Catalase and ascorbate peroxidase activities increased markedly under Fe treatment, particularly after the onset of oxidative stress. Catalase is one of the primary enzymes responsible for the rapid detoxification of $H_2O_2$, whereas ascorbate peroxidase removes $H_2O_2$ through the ascorbate glutathione cycle (Mittler, 2002). The enhanced CAT and APX activities observed in Fe- treated seedlings are consistent with previous reports showing induction of antioxidant enzymes under metal induced oxidative stress (Hasanuzzaman et al., 2020). The strong increase in CAT activity under 500 µM Fe during the early stages of exposure suggests a rapid response to elevated ROS production, while the gradual rise in APX activity indicates its involvement in sustained ROS detoxification during prolonged stress. Overall, the findings demonstrate that excess Fe disturbs redox balance in wheat seedlings in a concentration- and time-dependent manner. Enhanced CAT and APX activities represent important adaptive responses that alleviate oxidative damage, although prolonged exposure to high Fe levels ultimately results in significant membrane injury and growth suppression.

## 5. Conclusion

The present study demonstrated that the response of *Triticum aestivum* seedlings to excess Fe is strongly dependent on both Fe concentration and exposure duration. Moderate Fe supply (100 µM) promoted seedling growth and biomass, whereas prolonged exposure to higher Fe concentrations, particularly 500 µM, adversely affected root and shoot growth. Excess Fe induced oxidative stress, as evidenced by increased accumulation of $H_2O_2$ and MDA, indicating enhanced ROS generation and membrane lipid peroxidation. In response to this oxidative damage, antioxidant enzymes such as CAT and APX were markedly activated, suggesting their involvement in ROS detoxification and maintenance of cellular redox homeostasis. However, under prolonged exposure to high Fe levels, antioxidant defenses were insufficient to completely prevent oxidative damage. Overall, the findings highlight the concentration- and time- dependent nature of Fe toxicity in wheat seedlings and emphasize the importance of antioxidant defense mechanisms in mitigating Fe-induced oxidative injury. The findings of this study enhance our understanding of the physiological and biochemical responses of wheat to excessive Fe exposure and may aid in the development of effective approaches to improve Fe tolerance in crop species.

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**Table1: Effect of different Fe concentrations on shoot and root length (cm) of *Triticum aestivum* seedlings at different exposure periods**

| Concentration of Fe (μM) | Length (cm) | Days of growth | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2nd | 4th | 6th | 8th | 10th | 12th | 14th |
| Control | Shoot | 14.789±0.897 | 14.973±0.762 | 15.804±0.594 | 16.073±0.932 | 18.237±0.113 | 20.891±0.734 | 19.171±0.824 |
| | Root | 9.078±0.585 | 8.152±0.340 | 9.575±0.644 | 10.308±0.245 | 12.691±0.468 | 9.937±0.845 | 12.931±0.373 |
| 100 | Shoot | 15.811±0.327 | 16.352±0.409 | 15.472±0.995 | 14.121±0.402 | 20.659±0.586 | 23.247±0.797 | 19.127±1.031 |
| | Root | 10.288±0.955 | 9.075±0.865 | 9.551±0.443 | 8.651±0.457 | 12.364±0.503 | 11.729±0.635 | 12.063±0.570 |
| 200 | Shoot | 15.111±1.736 | 14.949±0.739 | 15.667±0.609 | 14.385±1.032 | 19.825±1.888 | 20.083±1.261 | 18.908±0.920 |
| | Root | 10.911±0.982 | 6.802±0.768 | 9.507±1.284 | 7.815±0.276 | 11.411±0.766 | 9.962±0.874 | 12.751±0.259 |
| 500 | Shoot | 14.022±0.764 | 15.344±0.197 | 12.434±0.511 | 15.027±0.459 | 19.596±0.808 | 17.754±0.673 | 16.980±0.547 |
| | Root | 8.555±0.443 | 8.130±0.815 | 9.185±0.541 | 8.616±0.949 | 11.174±0.512 | 8.343±0.747 | 9.883±0.309 |

**Table 2: Effect of varying Fe concentrations and exposure duration on fresh and dry weight of *Triticum aestivum* seedlings**

| Concentration of Fe (μM) | Weight (gm) | Days of growth | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2nd | 4th | 6th | 8th | 10th | 12th | 14th |
| Control | Fresh | 0.213±0.0191 | 0.185±0.0082 | 0.186±0.0102 | 0.191±0.0144 | 0.236±0.0005 | 0.234±0.0084 | 0.250±0.0113 |
| | Dry | 0.027±0.0023 | 0.0251±0.0014 | 0.0265±0.0003 | 0.0275±0.0015 | 0.0295±0.0003 | 0.0291±0.0022 | 0.0295±0.0008 |
| 100 | Fresh | 0.221±0.0263 | 0.183±0.0084 | 0.198±0.0140 | 0.176±0.0008 | 0.267±0.0105 | 0.277±0.0125 | 0.242±0.0159 |
| | Dry | 0.0253±0.0039 | 0.0239±0.0011 | 0.0270±0.0022 | 0.0249±0.0008 | 0.0321±0.0006 | 0.0367±0.0015 | 0.0296±0.0005 |
| 200 | Fresh | 0.232±0.0179 | 0.171±0.0038 | 0.196±0.0089 | 0.163±0.0107 | 0.244±0.0149 | 0.212±0.0119 | 0.237±0.0083 |
| | Dry | 0.0277±0.0023 | 0.0235±0.0010 | 0.0285±0.001 | 0.0247±0.0011 | 0.0295±0.0003 | 0.0290±0.0031 | 0.0305±0.0013 |
| 500 | Fresh | 0.202±0.0061 | 0.182±0.0020 | 0.163±0.0026 | 0.168±0.0110 | 0.235±0.0132 | 0.188±0.0137 | 0.200±0.0029 |
| | Dry | 0.0220±0.002 | 0.0250±0.0003 | 0.0255±0.0002 | 0.0269±0.0006 | 0.0318±0.0010 | 0.0291±0.0012 | 0.0273±0.0006 |

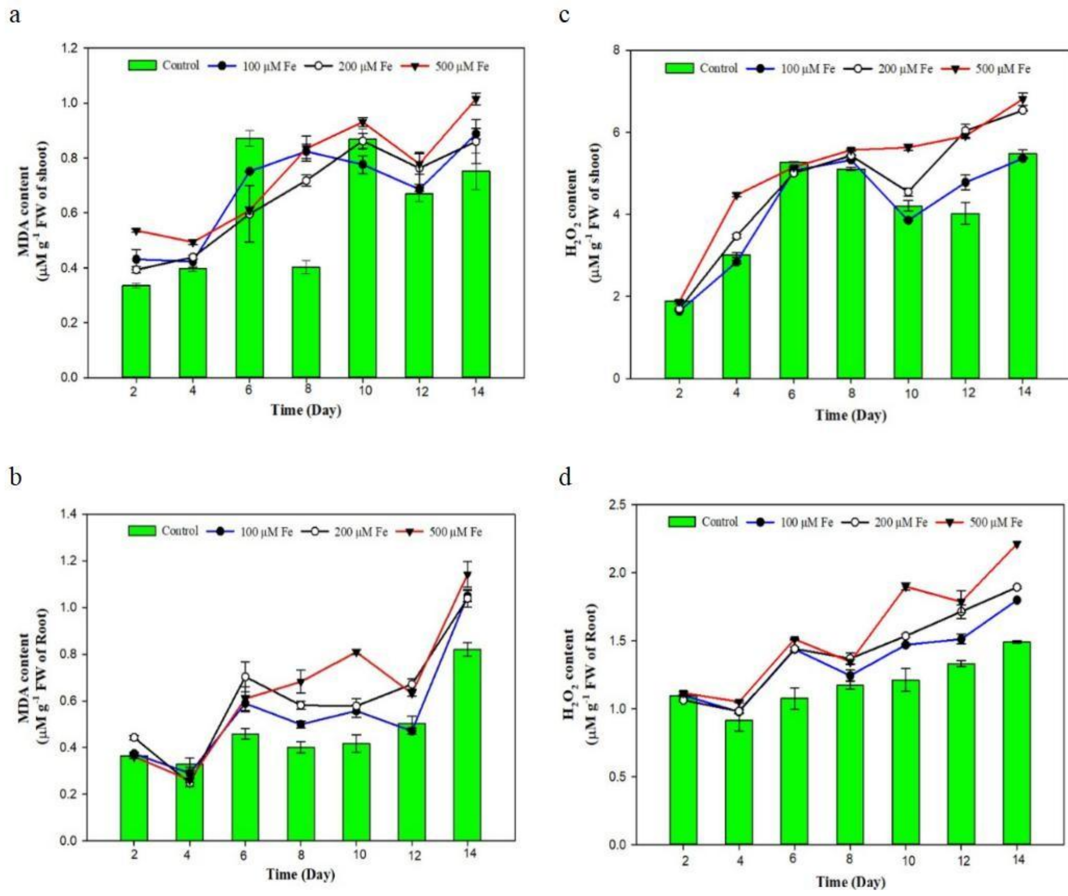


**Figure 1. Effect of varying Fe concentrations and exposure duration on MDA content in shoot (a), root (b) and $H_2O_2$ content in shoot (c), root (d) of *Triticum aestivum* seedlings.**

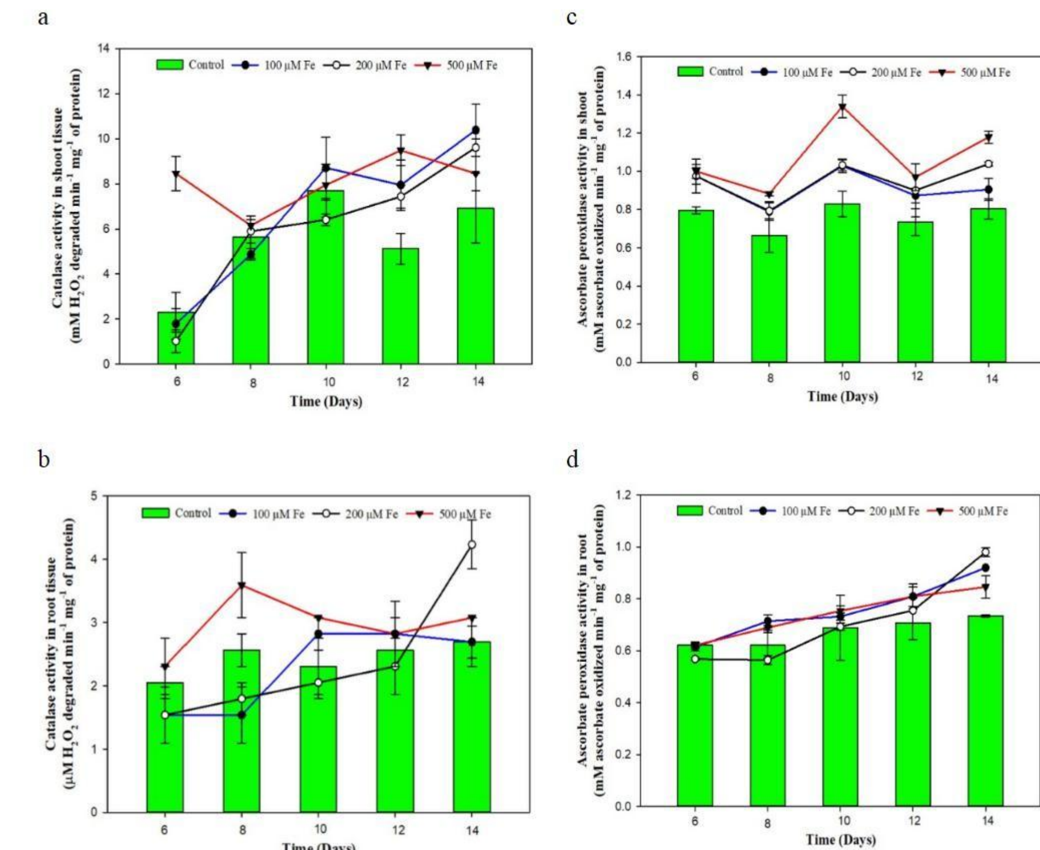


**Figure 2. Effect of varying Fe concentrations and exposure duration on Catalase activity in shoot (a), root (b) and Ascorbate peroxidase activity in shoot (c), root (d) of *Triticum aestivum* seedlings.**